Comments on "Seasonal variation of the main tidal constituents in the Bohai Bay" by D. Wang et al.

The seasonal variation of the principal tidal constituents M_2, S_2, K_1 and O_1 is studied in this discussion paper by analyzing the sea level observations at two stations in the Bohai Bay. The authors emphasize that in the previous studies the seasonal variation of the M_2 constituent has been fully investigated, while the other three have not been investigated. The authors further show that large semi-annual variation exists in S_2 and K_1 in their analyzed results. Since the paper contains some important improper treatments in data analysis, this paper needs major revision before publication. My comments are given below:

Major comments

1. The paper analyzes the observations monthly (month by month) to reveal seasonal variations of the obtained harmonic constants. The S_2 and K_1 results (Figures 3-5) show unreasonably large semi-annual (6-month period) modulation. I judge that this is due to the improper treatment in the harmonic analysis. That is, the unresolved constituents have not been removed in the analysis, resulting in spurious seasonality. To explain this, let us consider, as an example, the superposition of K_1 and P_1. This superposition can be expressed as follows (see, e. g., Fang et al., 1986; Pugh, 1987):

$$\zeta = H_{K_1}\cos\left(\tau + s + \frac{\pi}{2} - g_{K_1}\right) + H_{P_1}\cos\left(\tau + s - 2h - \frac{\pi}{2} - g_{P_1}\right) \qquad (1)$$

where ζ is the tidal elevation, H_{K_1} and H_{P_1} stand for amplitudes of the K_1 and P_1 constituents, g_{K_1} and g_{P_1} for phase-lags of the K_1 and P_1 constituents, τ is the mean lunar time reduced to angle, *s* and *h* the mean longitudes of the Moon and the Sun. Here for simplicity the nodal factors and corrections are left out of consideration. The above equation can be rewritten in the form

$$\zeta = MH_{K_1}\cos\left(\tau + s + \frac{\pi}{2} - g_{K_1} - \mu\right) \qquad (2)$$

where

$$M = \left[1 + R^2 + 2R\cos\left(2h + \pi + g_{P_1} - g_{K_1}\right)\right] \qquad (3)$$

$$\mu = \arctan\frac{R\sin\left(2h+\pi+g_{P_1}-g_{K_1}\right)}{1+R\cos\left(2h+\pi+g_{P_1}-g_{K_1}\right)} \qquad (4)$$

in which

$$R = H_{P_1}/H_{K_1} \tag{5}$$

If we assume that

$$g_{P_1} - g_{K_1} = 0, \text{ and } H_{P_1}/H_{K_1} = C_{P_1}/C_{K_1} \approx 0.331 \tag{6}$$

where C_{P_1} and C_{K_1} are coefficients of tide-generating potential for the P_1 and K_1 constituents, equal to 0.17543 and 0.53011, respectively (see e. g., Cartwright and Edden, 1973, or Fang et al., 1986), then M reaches its maximum, 1.331, when $h = \pi/2$ and $h = 3\pi/2$, or at the summer solstice and winter solstice. Similarly, M reaches its minimum, o.669, at the vernal equinox and autumnal equinox. From equation (4), with assumption (6), we obtain that the deviation of phase-lag μ reaches its maximum, 18.3° , when $h = -\pi/4$ and $h = 3\pi/4$, or at the middle time between the winter solstice and vernal equinox, as well as the middle time between the summer solstice and autumnal equinox. Similarly, the deviation reaches its minimum, -18.3° , at the middle time between the vernal equinox and summer solstice, as well as the middle time between the autumnal equinox and winter solstice. Comparing these quantities with the K_1 panels of Figure 3 we can conclude that the influences of P_1 on K_1 in the analysis of this paper were not removed, resulting in spurious strong semi-annul modulation. That is to say, the seasonality of K_1 shown in Figures 3-5 of this paper is greatly exaggerated, and should mainly be attributed to the influences of the P_1 constituent.

In the above we only show the influence of P_1 on K_1. In fact, the constituent ϕ_1 may also cause (but with smaller magnitude) semi-annual modulation in K_1; while ψ_1, and S_1 may cause annual modulation in K_1, and π_1 may cause ter-annual (four-month) modulation in K_1. Furthermore, it should be noticed that the S_1 constituent actually contains two parts: the astronomical part having an amplitude ratio of 0.78% to K_1; and the radiational part with magnitude depending on the strength of diurnal meteorological forcing. The latter part is generally much greater than the former in the coastal seas, and is actually not separable from the annual variation of K_1 by means of data analysis.

2. The signals of seasonality are usually weak, especially for the constituents S_2, K_1 and O_1, and the semi-annual variations. Thus the results derived from only one-year observations are not robust. It is suggested that authors use multiyear tidal gauge station data instead of one-year mooring data.

Other comments/suggestions

1. Page 1, lines 24-30: Fang and Wang (1986) first studied the seasonal variation of the constituents M_2, N_2, O_1 and M_4 in the Bohai Sea by introducing, as they called, the astrometeorological constituents.

2. Page 2, lines 5-20: When the monthly analysis is performed, the major part of influence of the unresolved constituents can be removed by using an inference procedure. Almost all classical tidal harmonic analysis programs have the function for inferring unresolved constituents (see, e. g., Foreman (1977); Wang and Fang (1981); Pawlowicz et al. (2002). An alternative approach can be found in Devlin et al. (2018).

3. Page 6, line 16: "Chen (2015)" was not given in the references.

4. Page 7, line 26 and page 17, caption of Figure 9: The word "rate" is improperly used.

5. Page 11, Tables 1 and 2: In the literatures on ocean tides, "phase lag" is convectional used instead of "phase". In addition, the reference time should be specified in relation to the phase lag.

6. The English writing needs substantial improvement. Better ask a native English speaker to edit the manuscript.

References

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